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ELECTRIC BLASTING CAP ASSEMBLY

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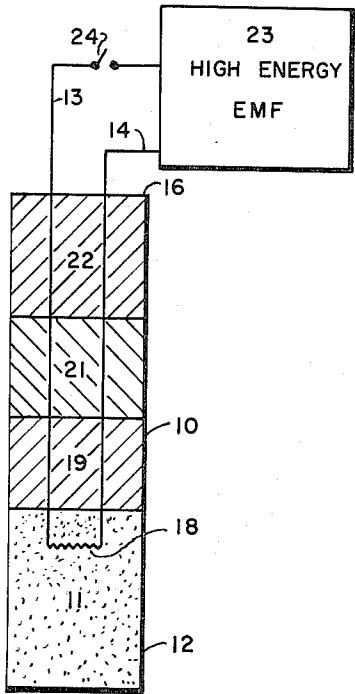


FIG. 1

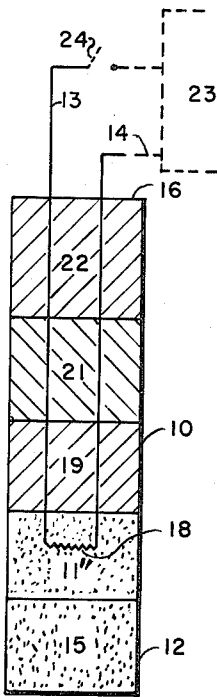


FIG. 3

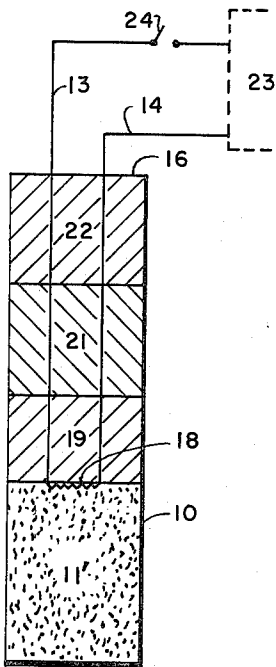


FIG. 2

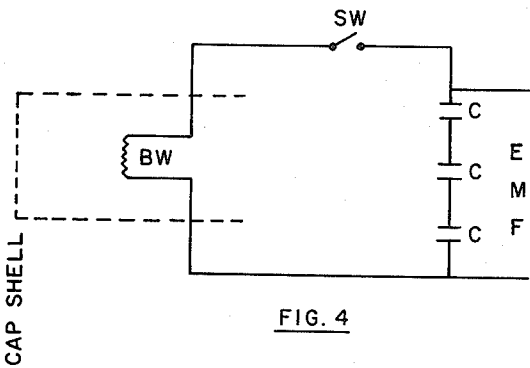


FIG. 4

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ELECTRIC BLASTING CAP ASSEMBLY

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6 Claims. (Cl. 102—28)

This application is a continuation-in-part of my co-pending application Serial No. 89,887, filed February 16, 1961, now abandoned.

This invention relates to electric blasting caps which are devoid of highly heat-sensitive ignition type compositions and contain only base charge type explosives to thereby exhibit improved high resistance to accidental discharge by impact, heat, static charges, and stray currents. In another aspect this invention relates to an electric blasting cap assembly in which the bridgewire is explodable upon passage of high energy E.M.F. therethrough to provide sufficiently high heat and shock energy to detonate a secondary type explosive without need for the conventional primer or ignition charge. In still another aspect, this invention relates to electric blasting caps devoid of highly heat sensitive ignition type compositions, as described, and containing PETN of density within a defined range alone, or, together with an additional and still less sensitive explosive charge. In still another aspect this invention relates to electric blasting caps which are markedly safer to handle than heretofore.

Electric blasting initiators of various designs are well known in the art. In general, they comprise a shell, generally elongated and metallic, containing an ignition system comprising an ignition plug, leg wires, and a bridgewire; a highly heat sensitive ignition mixture, generally loose or as a matchhead, around the bridgewire, and ignitable by heat developed by passage of current through the bridgewire via the leg wires; a primer charge detonatable by heat from burning of the ignition mixture; and a base charge detonatable in response to detonation of the primer. In some instances the primer charge and the ignition charge are one and the same. In that case, the primer is detonated in response to heat from the bridgewire and thereby initiates detonation of the base charge. Diazodinitrophenol, lead azide and mercury fulminate are exemplary of such primer-ignition compositions. Various sealing means, particularly for waterproofing the interior of the cap, are provided in the shell above the ignition plug, i.e., generally completely encompassing the leg wires extending from the ignition plug toward the power source.

The ignition and primer compositions normally used in electric blasting caps are, as is well known, highly sensitive to heat, impact, static electric charges, and stray currents so that accidental discharge is always a possibility that must be guarded against during manufacture, handling and utilization of such caps. It has accordingly, been proposed to eliminate the initiating charge and utilize only a secondary charge such as PETN or trimethylene trinitramine and to effect detonation by explosion of the bridgewire in response to passage of high energy E.M.F. therethrough. This has enabled manufacturing, handling and use with a marked increase in degree of safety. This invention is concerned with electric blasting cap assemblies, devoid of ignition and primer compositions of the type above described, characterized by explosive strength markedly higher than that of initiator-free blasting cap assemblies heretofore.

In accordance with the invention, an electric blasting cap is provided which comprises a closed shell; a pair of electrical conductor wires extending into said shell, and

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terminating therein; a bridgewire in said shell, explodable by passage of high energy E.M.F. therethrough, and connecting the terminal ends of said conductor wires; pentaerythritol tetranitrate, having a density of from 0.86 to 1.25 grams per cc., in said shell, and in direct contact with said bridgewire and detonatable in response to explosion of said bridgewire.

The invention in accordance with a preferred embodiment provides an additional explosive charge characterized by a brisance higher than that of the PETN charge and concomitantly of lower sensitivity so as to be detonatable only in response to detonation of the first charge. The additional explosive charge is disposed in detonating relationship with the PETN charge. The additional charge can be a PETN of density higher than that of the PETN charge in direct contact with the wire, or any other suitable high brisant explosive such as tetryl, TNT, HMX, RDX, nitromannite, and the like.

The invention, in another embodiment, utilizes as the sole charge, PETN of density and brisance comparable to that of the above described second charge, together with means for delivering the requisite high energy E.M.F. to the bridgewire. In a preferred practice of this embodiment, the bridgewire is positioned along the bottom side of the ignition plug and the plug is then pressed against the explosive charge to support the bridgewire at the plug-PETN interface so as to avoid breaking, or other damage to the bridgewire, during assembly. The result is an initiator of higher explosive strength than obtained utilizing only the lower density PETN charge, and is of strength comparable to that of the above described preferred embodiment. However, although only a single explosive charge is necessary, this embodiment is generally not preferred because of the high energy E.M.F. required for its detonation.

Regardless, however, of the arrangement of explosive charge or charges, the assembly of the invention is, in all events, devoid of any explosive charge which is in any manner sensitive to heat developed by passage of electric current through the bridgewire at an energy level below that causing the bridgewire to explode, thereby containing only those explosives which are well known in the art, per se, to be highly insensitive to impact, heat and static charges.

Any suitable means for supplying high energy E.M.F. to the bridgewire can be utilized, the requisite in any event being means for passing electrical energy through the bridgewire via the conductor wires in an amount substantially in excess of the energy required for melting the bridgewire, generally at least 10^2 to 10^6 times that required for melting the said bridgewire.

The invention is illustrated with reference to the drawings, of which FIG. 1 is a front sectional view of an electric blasting cap assembly of this invention containing PETN as the sole explosive charge, and in which the bridgewire is disposed within the said charge; FIG. 2 is a front sectional view of an assembly the same as that of FIG. 1 except that the PETN charge is of relatively high density and of such high brisance and density that the bridgewire is, from the standpoint of practicability, pressed against the explosive charge by the ignition plug at the plug-charge interface; FIG. 3 is a front sectional view of a blasting assembly similar to that of FIG. 1 except that an additional body of a detonatable explosive charge of brisance greater than that of the first charge is present to provide an assembly of increased explosive strength; and FIG. 4 is illustrative of suitable firing circuits for the assemblies of FIGS. 1-3.

Referring to FIG. 1, elongated shell 10, generally metallic, contains PETN having a density within the range of from 0.86 to 1.04 grams per cc. as an explosive charge

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11, in the closed end 12. Lead wires 13 and 14 extend into shell 10 through the open end 16 and terminate within charge 11. Bridgewire 18, within charge 11, connects lead wires 13 and 14 at their points of termination, and is explodable by high energy E.M.F. passed therethrough via lead wires 13 and 14. A dielectric plug 19 (ignition plug) in shell 10 directly above charge 11 transversely closes shell 10 and is disposed against charge 11 as a confining means therefor. Although dielectric plug 19 is generally, in itself, a sufficient waterproofing, it is preferred to utilize supplementary waterproofing means such as asphalt plug 21 directly above plug 19 and sulfur top-

ping 22. Charge 11, in direct contact with bridgewire 18, is detonatable in response to impact by heat and shock energy developed by explosion of bridgewire 18, the latter initiated by high energy E.M.F., as described more fully hereinafter. Charge 11 is nondetonatable by heat energy developed by passage of electric energy through bridgewire 18 when short of that causing explosion of bridgewire 18.

As is well known in the art, brisance and density of detonatable explosives are closely related, inasmuch as brisance increases with increased density. However, as is also well known, with increasing density, the sensitivity of those explosives decreases so that a greater amount of energy is required for their detonation.

Charge 11, in the embodiment of FIG. 1, is, from the standpoint of preferred operation, pressed in shell 10 to a density defined hereinabove (0.86 to 1.04 grams per cc.), such that it can be detonated by passage of a moderate amount of high energy E.M.F. through bridgewire 18, generally from 10^2 to 10^4 times the amount of energy required for melting the bridgewire. Under these density and firing conditions, sufficient brisance for many requirements is obtained. An overpress of the charge 11 of say from $\frac{3}{4}$ to $\frac{5}{4}$ inch, dependent on the particle size, as described more fully hereinafter, generally provides a suitable density of charge 11 in the preferred range.

High energy electrical source 23, such as a bank of charged condensers, as illustrated more fully with reference to FIG. 4 is connected with lead wires 13 and 14 for delivery of a large amount of current through bridgewire 18 via switch 24 for a short time interval to cause explosion of bridgewire 18. In carrying out the embodiment of FIG. 1, source 23 is generally adapted to deliver a pulse of energy to the bridgewire at a potential in the order of say, from 2000-5000 volts, although the most suitable potential may be outside that range dependent upon the particular composition of the bridgewire 18.

As described with reference to FIG. 1, I prefer to utilize a PETN charge which is detonatable in response to explosion of the bridgewire when initiated by a moderate amount of high energy E.M.F. However, as above stated, it is within the scope of the invention to utilize a higher brisant PETN charge than that contemplated in the embodiment of FIG. 1. Such charge is, of course, characterized by an accompanying increase in density, i.e., in the range of from 1.04 to 1.25 grams per cc., and decrease in sensitivity, which requires supply of a correspondingly increased amount of high energy E.M.F. to the bridgewire for its detonation. This embodiment is further illustrated with reference to FIG. 2, in which all parts, the same as those of FIG. 1, are like numbered and are not again discussed in detail. Referring to FIG. 2, charge 11' is characterized by a brisance, and accompanying density, higher than those of charge 11 of FIG. 1, and due to its lower sensitivity, requires delivery of correspondingly greater amount of high energy E.M.F. to the bridgewire 18, i.e., at least 10^4 times the amount required for melting the bridgewire 18 and up to 10^6 times that amount. Due to the higher density of charge 11', i.e., than charge 11, the bridgewire 18 cannot be pressed

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into it during assembly of the blasting cap without the likelihood of damage to the bridgewire. Accordingly, in assembly of the blasting cap of FIG. 2, bridgewire 18 is disposed along the bottom side of plug 19 so that when the ignition assembly is inserted into the shell 10, wire 18 is pressed by plug 19 against explosive charge 11' at the plug-explosive interface without danger of breakage of the bridgewire. The embodiment of FIG. 2, therefore, provides for PETN characterized by a brisance higher than that of FIG. 1, as the sole explosive charge, without the danger of failure of the bridgewire than can be expected from breakage that may occur when endeavoring to dispose it within the explosive charge in accordance with standard practice.

When utilizing a relatively high brisant PETN, as the sole explosive charge, as illustrated with reference to FIG. 2, the corresponding increase in high energy E.M.F. required is in many instances undesirable from the standpoint of equipment requirements and associated problems that accompany such operations. Accordingly, when such high brisance as that of the charge 11' of FIG. 2, is desired, it is generally preferred to utilize a second detonatable charge, e.g., PETN, HMX, RDX, TNT, tetryl, nitromannite, and the like in addition to the sole charge of FIG. 1 and detonatable, in the assembly, only in response to detonation of the initial charge. In this manner the desired high brisance is accomplished without the need for supplying the high energy E.M.F. required in the embodiment of FIG. 2.

Referring to FIG. 3, in which parts the same as those of FIG. 1 are numbered the same and are not again discussed in detail, charge 11'' is PETN characterized by the same density, sensitivity and brisance as those of charge 11 of FIG. 1 and is in direct contact with bridgewire 18, the said wire 18 preferably being disposed within the charge 11'' as in the embodiment of FIG. 1. Charge 15, which can also be PETN but can be any suitable detonatable explosive charge, as above described, is of higher brisance than that of charge 11'', and is accordingly less sensitive than charge 11'' and is not detonatable by the explosion of bridgewire 18 even if it were in direct contact with wire 18. Charge 15 is, however, detonatable in response to detonation of charge 11'' and is disposed in shell 11 intermediate charge 11'' and closed end 12 in detonating relationship with charge 11''.

As particularly illustrated with reference to FIG. 4, any suitable high electric energy source can be employed, e.g., any suitable pulse powered source, modulator, or electric device which will supply a large current through the bridgewire for a short interval of time, i.e., high power for a short time. Such a high electric energy source provides an electric impulse having a steep wave front. Thus, current is delivered (E.M.F.) to capacitors C. When the firing switch SW (switch 24, FIGS. 1-3) is closed, high energy current is delivered to the bridgewire BW (wire 18, FIGS. 1-3) at a large number of amperes within a short period, say, a rise to the order of 1000 to 10,000 amperes in less than one microsecond, dependent upon the impedance of the circuit.

Inasmuch as sensitivity of PETN decreases with increase in density, the sensitivity of the PETN charges 11, 11' and 11'' is advantageously regulated by pressing the plug 19 onto the unpressed PETN charge to compress the PETN a predetermined degree (overpress) in order to accomplish the desired increase in density. Generally, the PETN in the 0.86 to 1.04 density range can be detonated by impact from the explosion of the bridgewire initiated by from 10^2 to 10^4 times the amount of energy required for melting the bridgewire. The above densities (0.86-1.04) are generally from 1.1 to 1.4 times that of the uncompressed, or loose, PETN, dependent, of course, on particle size of the loose, or unpressed, charge. The relationship of brisance and sensitivity to density, and of overpress to particle size in the attainment of density are

well known, and can be correlated by one skilled in the art. Thus, by way of example, PETN of the embodiments of FIGS. 1 and 3, i.e., charge 11 or 11', is advantageously pressed to an overpress of about $\frac{3}{64}$ inch, when the particle size of the unpressed material is in the range such that all passes through a 30 mesh (per inch) screen and all is on a 140 mesh screen, to yield a density of the PETN of about 0.93 gram per cc. which is about 1.15 times that of the initially loose mixture, and is detonatable by explosion of the bridgewire when initiated by passage of energy therethrough in an amount about 10^3 times that required for melting the bridgewire.

When utilizing a higher brisant PETN as the sole explosive charge as illustrated with reference to FIG. 2, and which requires more than about 10^4 times the amount of energy needed for melting the bridgewire, the particle size and confinement pressure are correlated to provide the correspondingly high densities of from about 1.04 to about 1.25 grams per cc., which are up to about 1.6 times those of the loose, or unconfined charge, say 1.4 to 1.6 times.

The following tabulation of data, Table 1, illustrates the effect of degree of overpress on sensitivity, and its relationship, therefore, to density of the PETN charge. The data also illustrates correlation of overpress (or density) with firing conditions to provide sufficient high energy E.M.F. for explosion of the bridgewire and detonation of the PETN charge. Also demonstrated is that PETN density must be within a critical range in order that, in a given series of shots, no "D" type shots (low order detonations) will be obtained. Thus, at a firing voltage of 3000 at 12.5 microfarads (Table 1), several "D" shots were obtained at an overpress below $\frac{3}{64}$ inch, i.e., below a PETN density of about 0.86 gram per cc., and again at an overpress greater than $\frac{3}{64}$ inch, i.e., a density of about 1.04 grams per cc. At an overpress of from $\frac{3}{64}$ to $\frac{5}{64}$ inch inclusive, i.e., a density of the overpressed PETN of from about 0.86 to 1.04 grams per cc., no "D" shots were obtained. Further correlations of density of the PETN charge with the requisite amount of high energy E.M.F. for explosion of the bridgewire and detonation of the PETN charge are particularly apparent to one skilled in the art, particularly in light of the following data.

In carrying out the tests set forth in Table 1 below, each firing was made with an electric blasting cap formed from a $\frac{1}{8}$ inch bronze shell and containing 0.40 gram PETN, the same as that disposed around the bridgewire in the Caps A described hereinbelow, the latter superposed on 0.40 gram PETN pressed into the bottom of the shell at about 3000 p.s.i.g. The ignition plug, adjacent the superposed PETN, was formed from plastic (Bakelite) beyond the bottom of which the lead wires extended $\frac{1}{64}$ inch into the superposed PETN and were connected at their terminated ends with a 0.003 inch diameter Tophet C wire 0.010 inch in length.

Table 1

Overpress, Inches	Firing Voltage at 12.5 Microfarads								
	3,000			2,500			2,000		
	S	D	A	S	D	A	S	D	A
Flush (no confinement, i.e., zero overpress)-----	25	4	21	25	2	23	---	---	---
$\frac{2}{64}$ -----	50	0	50	25	0	25	25	1	24
$\frac{4}{64}$ -----	525	0	525	25	0	25	25	3	22
$\frac{6}{64}$ -----	50	0	50	25	0	25	25	2	23
$\frac{8}{64}$ -----	25	0	25	25	6	19	---	---	---
$\frac{10}{64}$ -----	25	2	23	---	---	---	---	---	---

S=Total number of caps shot. D=Number of unsatisfactory plate shots. A=Successful plate shots. Although low order detonation was in most instances obtained in the "D" shots, such was insufficient to blow a hole through the lead plate. In all "A" shots a hole having a diameter in the order of about 10 mm. was blown through the plate. See further description of plate test elsewhere herein.

Data of Table 1, i.e., at 3000 volts at 12.5 mcfd., incorporated into Table 2, following, are further illustrative of the invention.

Table 2

Density (grams/cc.)	Superposed PETN ¹			Firing at 3,000 Volts and 12.5 mfd.s. ²		
	Degree of Pack	Length of Mass, Inches		S	D	A
0.78	Loose ³ -----	0.60		---	---	---
0.82	Loosely packed ⁴ -----	0.56		25	4	21
	Overpress, inches:					
0.86	$\frac{2}{64}$ -----	0.53		50	0	50
0.91	$\frac{4}{64}$ -----	0.50		525	0	525
0.97	$\frac{6}{64}$ -----	0.47		50	0	50
1.04	$\frac{8}{64}$ -----	0.44		25	0	25
1.12	$\frac{10}{64}$ -----	0.41		25	2	23

¹ Same as PETN disposed around the bridgewire in Cap A of Table 3 infra.

² S, D, A as defined, see Table 1 supra.

³ As introduced into shell--no applied packing.

⁴ Loose PETN packed by vibratory action only. Ignition plug in position with zero overpress.

Although low order detonation was in most instances obtained in the "D" shots, such was insufficient to blow a hole through the lead plate. In all "A" shots a hole having a diameter in the order of about 10 mm. was blown through the plate. See further description of plate test elsewhere herein.

As shown in Table 2, the loose (no applied packing) superposed PETN charge had a density of 0.78 gram per cc. whereas the superposed PETN charge, when loosely packed by vibratory action, had a higher density, i.e., 0.82 gram per cc. Even the higher density "loosely packed" PETN gave 14 "D" type shots, i.e., of low order detonation. Also as shown, in the density range of the superposed PETN at an overpress of from $\frac{3}{64}$ inch to $\frac{5}{64}$ inch, viz., 0.86 to 1.04 grams per cc., all shots were of high order detonation, i.e., type "A," whereas at $\frac{10}{64}$ inch, i.e., density=1.12, there were 8 type "D" shots. These data again demonstrate low order detonations that are obtained when the PETN density is either unduly low or unduly high.

It is to be understood, of course, that in the fabrication of the assemblies of the invention, any suitable means for attaining the desired density of the charge to be detonated by explosion of the bridgewire can be utilized such as, for example, compression in the shell by conventional pin means, or direct introduction, into the shell, of the PETN charge preformed at the required density.

The now preferred method for assembly of a blasting cap of this invention is quite apparent in light of the foregoing. Thus, the loose PETN explosive charge is introduced into an elongated shell, closed at one end, and the ignition assembly, i.e., the ignition plug 19, leg wires 13 and 14, and bridgewire 18, all as a unit, is then inserted into the shell through the open end onto the confined PETN, the bridgewire being disposed in advance of the plug so as to enter the explosive body and be within the explosive body at the time the plug initially contacts the explosive. The desired degree of overpress is then imposed and the assembly is then completed by superposing a layer of asphalt waterproofing on the ignition plug and a sulfur topping on the asphalt layer.

When an additional charge of detonatable explosive is to be employed in practice of the embodiment of FIG. 3, it is inserted into the closed end of the elongated shell and pressed to the desired density by conventional pin means. The PETN charge is then introduced into the shell, superposed on the previously compressed charge, and the above procedure involving confinement of the PETN by overpress carried out.

When fabricating the embodiment of FIG. 2, confinement is, of course, accomplished in the same manner except that the leg wires terminate on the bottom side of the ignition plug and are connected at those points by the bridgewire. The compression to the relatively high density is then accomplished without the need for the bridgewire to enter the PETN body, so that there is no

possibility of breakage of the bridgewire in obtaining the desired overpress to attain the desired high density. In fabricating the assembly of FIG. 2, it is desirable to utilize a PETN of rather small particle size so as to compensate for the large degree of overpress that might otherwise be required.

The following tabulation of data, Table 3, summarizes the results of sensitivity tests made with a blasting cap of the invention (Cap A) and with four conventional types (Caps B, C, D and E).

Table 3

Blasting Cap ¹	Static Sensitivity (shunt to shell)	Maximum nonfiring current	Impact Sensitivity	
			Over The Entire Cap	Over The Ignition Zone Only
A-----	>35 k. volts-----	>23 amps-----	>77"	>77"
B-----	20 k. volts-----	0.25 amps-----	29"	11"
C-----	25 k. volts-----	0.40 amps-----	35"	11"
D-----	1,000-2,000 volts-----	0.25 amps-----	29"	11"
E-----	1,000-2,000 volts-----	0.30 amps-----	35"	11"

¹ Cap A, bronze shell, 1 1/2" in length by 0.275" in diameter; PETN* as base charge, 0.40 gram; PETN† as main charge around the bridgewire, 0.40 gram; a Tophet "C"‡ bridgewire, 0.10" in length by 0.003" in cross-sectional diameter.

Cap B, bronze shell, 1 1/2" in length by 0.275" in diameter; diazodinitrophenol (DDNP) as a primer (and ignition) charge, 0.30 gram; PETN* as a base charge, 0.40 gram; and Pt/Rh/Ru bridgewire 0.114" in length by 0.0012" in cross-sectional diameter.

Cap C, bronze shell, 2" in length by 0.275" in diameter; DDNP as a primer charge, 0.22 gram; PETN* as a base charge, 0.4 gram; LMNR§/KClO₃ 80/20, as an ignition mixture, 0.1 gram; and a Tophet "C" bridgewire, 0.10" in length by 0.002" in cross-sectional diameter. Contains antistatic mechanism.

Cap D, bronze shell, 4" in length by 0.275" in diameter; DDNP as a primer charge, 0.30 gram; PETN as a base charge, 0.40 gram; Pb/Se/Te/Si as an ignition mixture, 0.75 gram; and a Pt/Rh/Ru bridgewire, 0.114" in length by 0.001" in cross-sectional diameter; BaO₂/Se/Te as a delay fuse, a core 1" in length by 1/8" in diameter in a lead tube intermediate the ignition and primer composition.

Cap E, bronze shell, 4 1/4" in length by 0.275" in diameter; DDNP as a primer charge, 0.33 gram; PETN as a base charge, 0.40 gram; as an ignition mixture, Pb/Se/Si/PbStearate, 0.75 gram; and a Pt/Rh/Ru bridgewire 0.114" in length by 0.001" in cross-sectional diameter.

* Conventional pressed PETN base charge for electric blasting caps.

† 0% on 30 mesh; 20-30% on 60 mesh; 60% on 140 mesh and remainder through 140 mesh; 1/2" overpress; density=0.86 gram per cc.

‡ Ni-Cr-Fe.

§ Lead Mononitroresorcinate.

In carrying out the above impact tests, i.e., to determine sensitivity of the cap to impact by a falling object, the cap in each instance was placed in a horizontal position on a solid steel plate supported by heavy concrete. A 10-lb. weight 1 1/2" in diameter was dropped from the indicated height directly onto the section of the cap containing the detonatable charge. The height shown is the maximum at which five consecutive caps failed to explode or detonate in response to fall of the 10-lb. weight. In the measurement of impact sensitivity of the ignition zone only, i.e., area surrounding the bridgewire, the force or the 10-lb. weight was transmitted through a 1/4" x 1/4" x 3" steel bar placed perpendicularly to the length of the cap and over that part of the cap containing that most sensitive zone.

The static sensitivity tests reported above are made in accordance with procedure well known in the art for testing an electric blasting cap for likelihood of being shot accidentally by a static discharge. Thus, a high voltage current is discharged, for example, from a high voltage capacitor through the shunted lead wires to the bridgewire terminals and from either of the lead wires, or both, through the charge to the shell. The test determines the conditions under which the cap is fired either by heating of the powder or the bridgewire by passage of the static discharge through it as the charge travels from one lead wire to the other depending on the terminal from which the static charge moves. The voltage reported in each

test was that required to shoot the cap from discharge of a 750 mmfd. condenser. Additional tests, with similar results, were made with Cap A using a 3000 mfd. condenser or capacitor, thus further demonstrating the safety provided by the cap assemblies of this invention.

About one thousand Caps A of the above tabulation with variances were shot under firing conditions of 3000 volts and 12.5 microfarad capacitor discharge in carrying out a lead plate test which involves shooting the cap when positioned with the end containing the charge in contact with the surface of a lead plate 0.16 inch thick. The shots, in each instance, blasted a hole through the plate, in the order of 10 mm. in diameter.

The above tabulation illustrates the marked insensitivity of the blasting cap assemblies of this invention as compared with sensitivity of conventional caps in respect to high maximum nonfiring current, marked decrease in impact sensitivity, and resistance to accidental discharge by static electric charges.

The diameter of the bridgewire in any instance is, of course, to be correlated with the particular wire material and with the firing energy contemplated in the given instance. Generally, however, the bridgewire diameter will be in the range of about 0.0004 to 0.010 inch, 0.002 to 0.004 inch being more often employed.

Any bridgewire composition, and dimensions, generally employed in the electric blasting cap art, can be employed in the practice of the invention. Also, any suitable combination of current and voltage conditions that can supply the necessary high energy E.M.F. to the bridgewire can be utilized. The following tabulation summarizes firings made employing a PETN-containing assembly, Cap A of the above tabulation, with the variances indicated. Plate test measurements were made in all instances and excellent plate test results were obtained. The reported voltage-current values in each instance do not necessarily represent the minimum or optimum energy values but illustrate a number of these values than can be utilized, selection of optimum firing conditions in any given instance being always dependent on the sensitivity of the particular PETN charge.

Bridgewire Composition	Length x Diameter	Firing voltage at 12.5 microfarads	Multiple of Energy for Melting the Bridgewire
Tungsten-----	0.10" x 0.0004"-----	6,000	80,000
Do-----	0.10" x 0.0007"-----	8,000	50,000
Do-----	0.10" x 0.0022"-----	2,000	300
Tophet "C"-----	0.10" x 0.00225"-----	2,000	700
Do-----	0.10" x 0.003"-----	2,000	400
Do-----	0.10" x 0.004"-----	2,000	220
Nichrome-----	0.10" x 0.002"-----	2,000	800
Do-----	0.10" x 0.009"-----	6,000	400
Do-----	0.10" x 0.0159"-----	8,000	250
Pt/Rh/Ru-----	0.114" x 0.0012"-----	2,500	2,500
Pt/Al-----	0.10" x 0.003"-----	2,000	400
Chromel "C"-----	0.10" x 0.010"-----	7,000	400
Alloy "1000"-----	0.10" x 0.0031"-----	5,000	2,500

The terms "PETN," "HMX" and "RDX," TNT, tetryl, as set forth throughout the specification are designations well known in the explosives art. Thus, "PETN" designates pentaerythritol tetranitrate; "HMX" designates cyclotetramethylenetetranitramine; "RDX" designates cyclotrimethylenetrinitramine; TNT designates trinitrotoluene; tetryl designates trinitrophenylmethylnitramine.

As will be evident to those skilled in the art, various modifications can be made or followed, in the light of the foregoing disclosure and discussion, without departing from the spirit or scope of the disclosure or from the scope of the claims.

What I claim and desire to protect by Letters Patent is:

1. An electric blasting cap assembly comprising a closed shell; a pair of electrical conductor wires extending into said shell and terminating therein; a bridgewire within said shell connecting the terminal ends of said conductor wires and detonatable in response to passage of a high

energy electric current therethrough when in an amount of from 10^2 to 10^4 times greater than that required for melting the bridgewire; and pentaerythritol tetranitrate, having a density of from 0.86 to 1.04 grams/cc., within said shell, in direct contact with said bridgewire.

2. A blasting cap assembly of claim 1 wherein the said PETN is the sole explosive charge.

3. In a blasting cap assembly of claim 1 an additional explosive charge nondetonatable in response to detonation of said bridgewire but detonatable in response to detonation of said PETN and disposed in detonatable relationship with said PETN.

4. A blasting cap assembly of claim 3 wherein said additional explosive charge is selected from the group consisting of pentaerythritol tetranitrate, cyclotetramethylenetetranitramine, cyclotrimethylenetrinitramine, nitromannite, trinitrotoluene and trinitrophenylmethylnitramine.

5. In a blasting cap assembly of claim 1 a dielectric body within said shell as a closure therefor positioned in

contact with said PETN to confine same within said shell, and said conductor wires extending through said dielectric body into, and terminating in, said PETN, whereby said bridgewire is disposed within the mass of said PETN.

6. In an assembly of claim 1 means external to said shell and connected with said conductor wires for delivering said electrical energy thereto.

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